Agenda

Maritime Systems Technology Office

Fuel Cells

Precision Navigation

Acoustic Communications

Automated Surveillance Network

Magnetic Communications

Future Programs

#590
94-F-0331

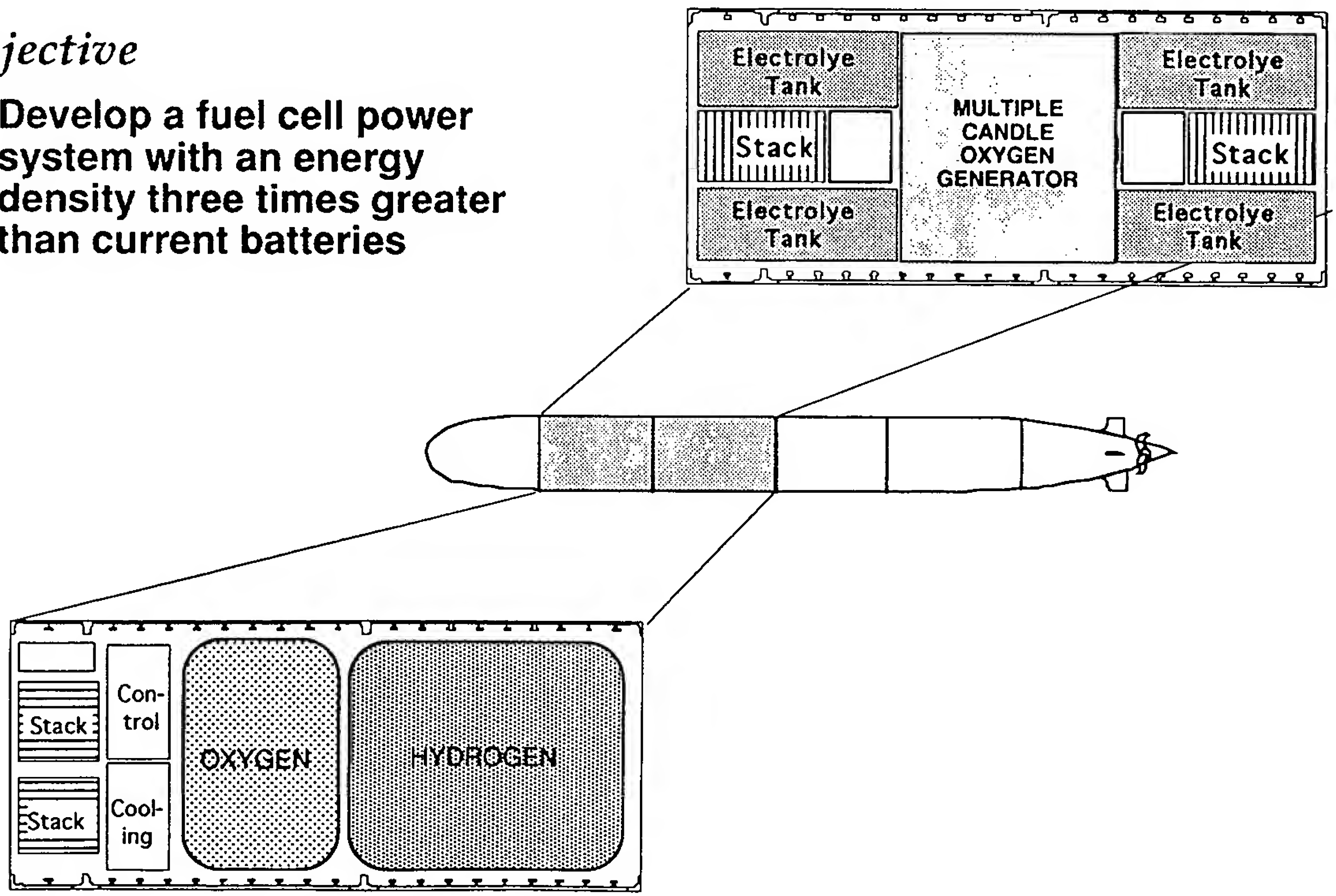
MSTO Organization

- **Director** — Mr. C. E. Stuart
  - Program Management — Mr. T. Griffin
  - UUV Coordinator — CAPT A. Beam
  - SUBTECH Coordinator — CAPT R. Lowell
  - Technology Reinvestment Coordinator — Mr. P. Rosenstrach
  - **Deputy Director** — CAPT E. Mihalak
    - UUV/MCM — CAPT Alan Beam
    - Shallow Water ASW — Dr. Bill Carey
    - Maritime Platform Technologies — Dr. Ed Carapezza
    - C3I/Synthetic Environments — CAPT Chris Johnson
    - Simulation Based Design — Mr. Gary Jones
    - Ship Systems Automation — CAPT Bob Lowell
    - Advanced Structural Technologies — Mr. Steve McBurnett
    - National Shipbuilding Initiative — Mr. Bob Schaffran

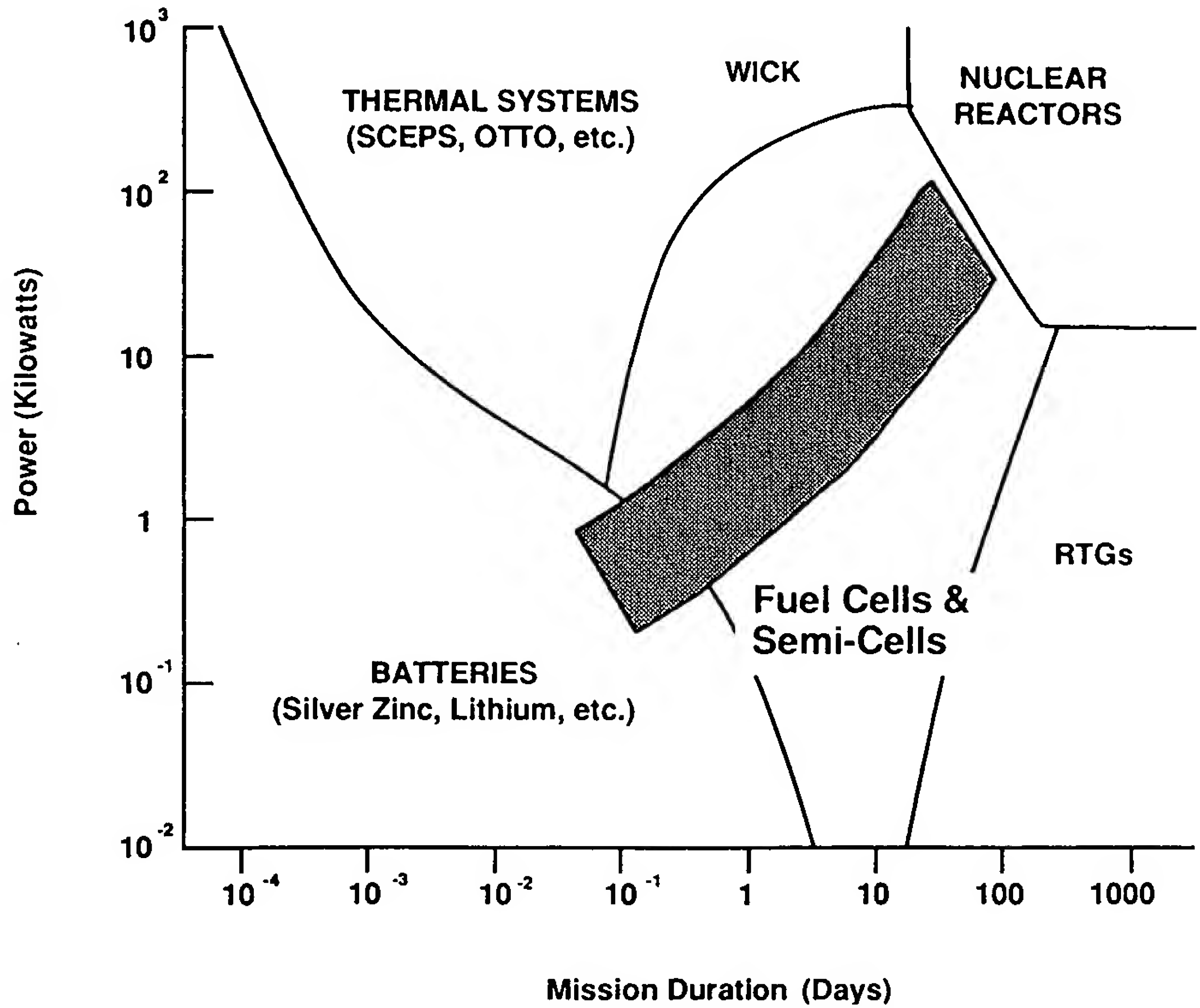
UUV Fuel Cell Program

Objective

Develop a fuel cell power system with an energy density three times greater than current batteries



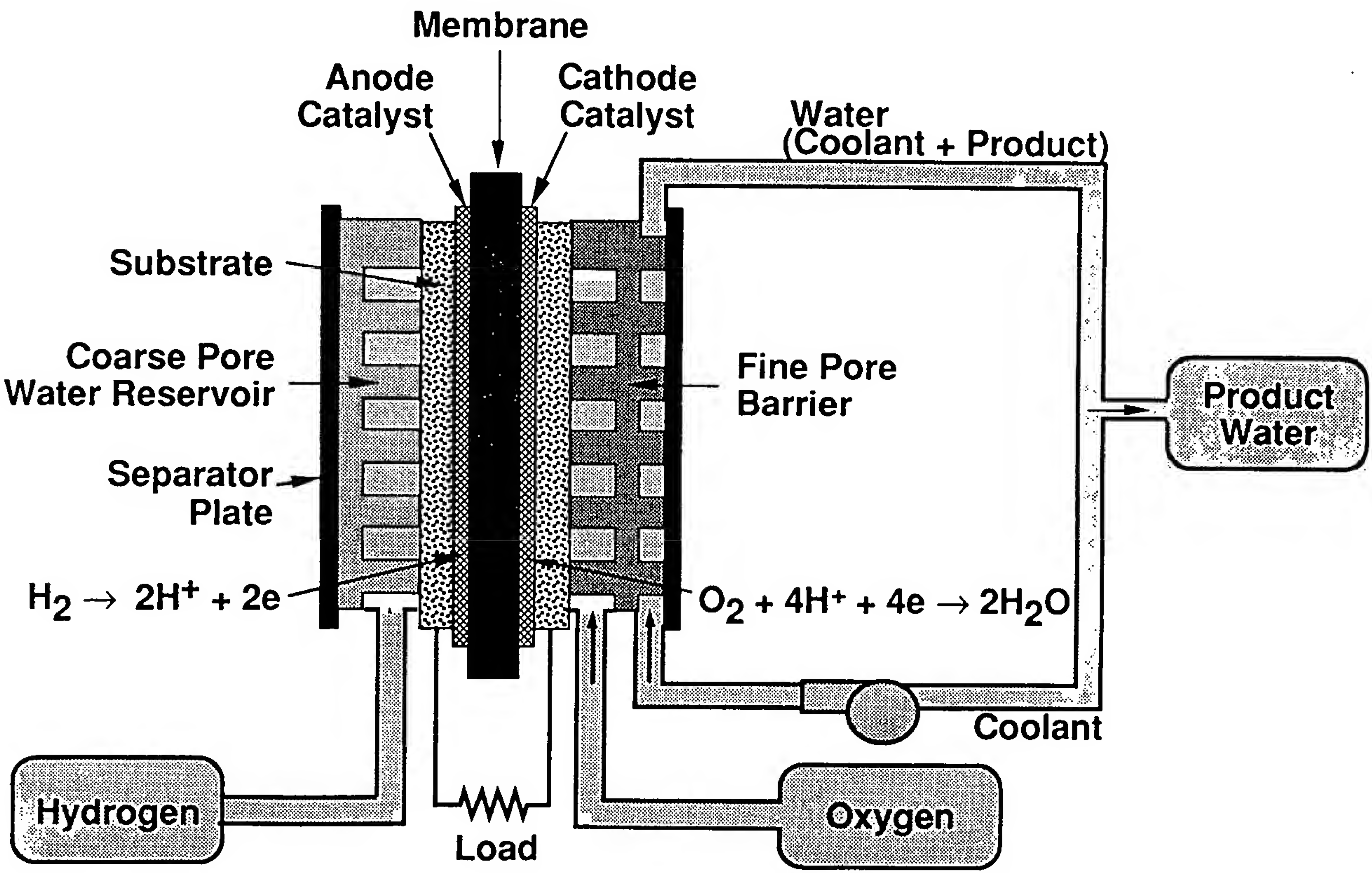
Energy Alternatives



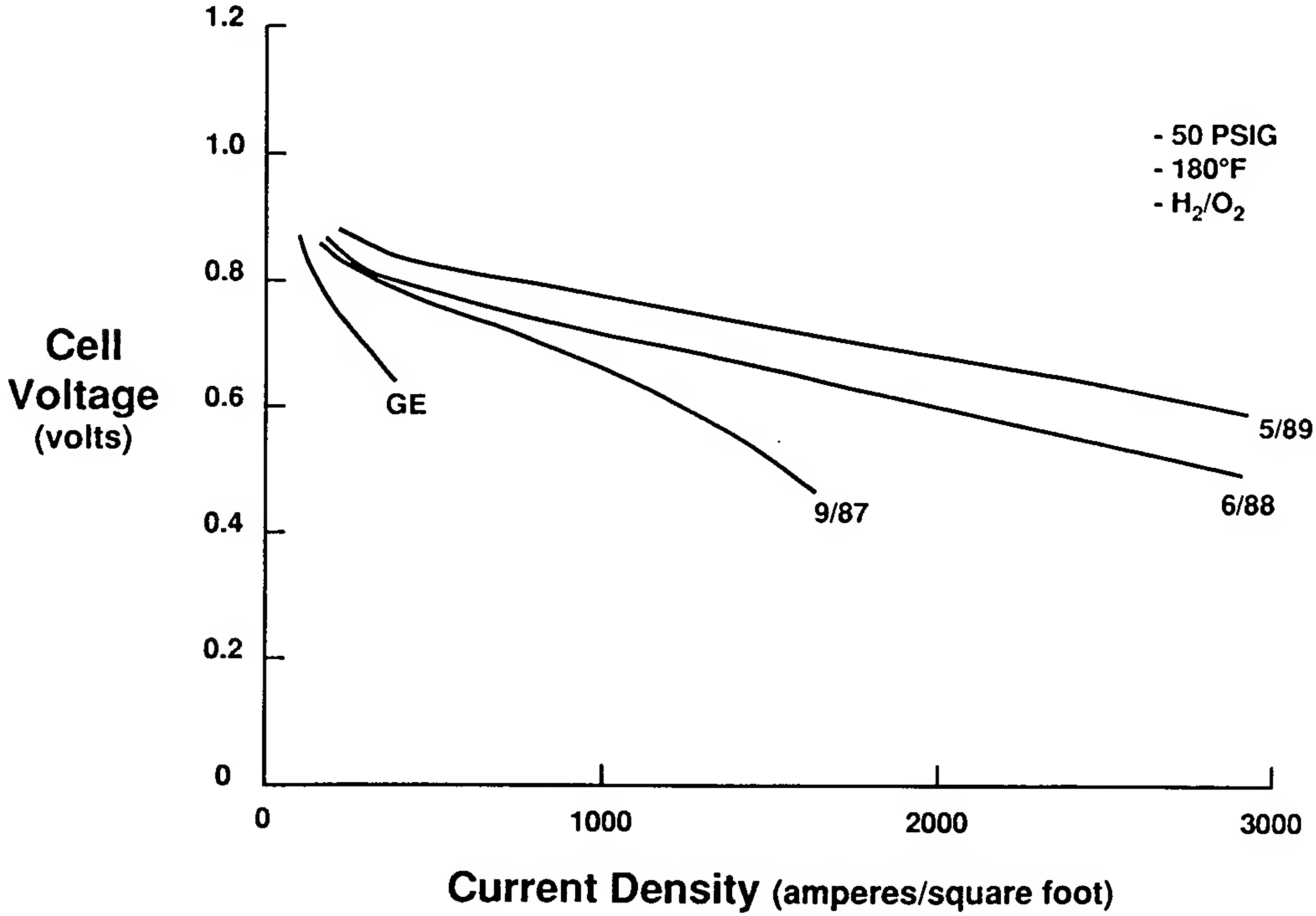
Fuel Cell Types and Applications

Type	Advantages	Applications
Proton Exchange Membrane (PEM)	*Commercial at small scale* Low temperature (fast starting)	UUVs and submarines Portable equipment Zero-emission vehicles
Alkaline	*In production for NASA*	Space
Phosphoric Acid	*Available commercially* Medium temperature	Stationary power
Molton Carbonate and Solid Oxide	*MCFC is nearly commercial, SOFC is developmental* High temperature (constant operation) Fuel versatile Very Efficient (molton carbonate)	Stationary power Large vehicles

Proton Exchange Membrane Fuel Cell

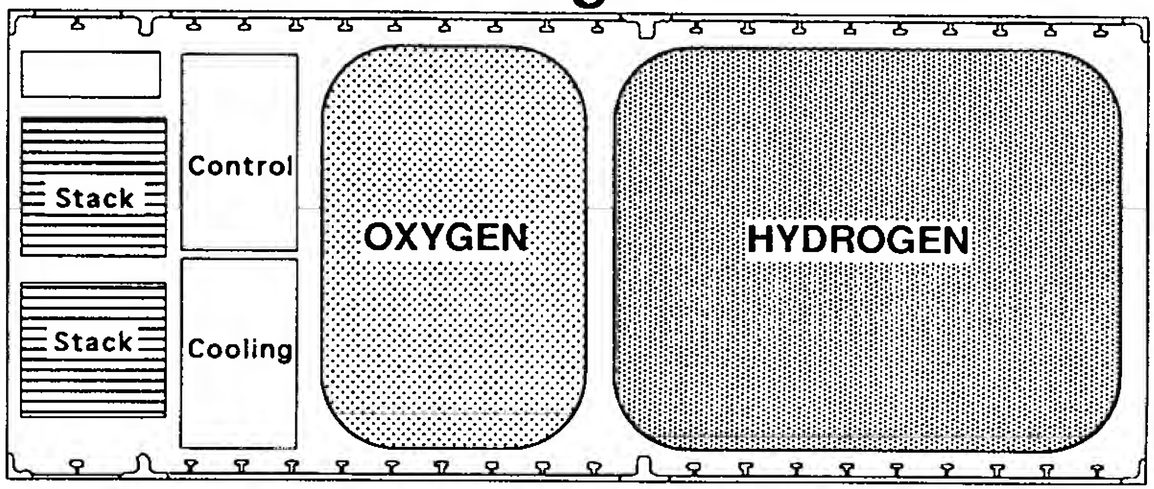


PEM Performance Evolution



Fuel Cell Power System

Proton Exchange Membrane



International Fuel Cells

Technical Challenges

- Precision assembly of stack
- Passive water removal without Dryout or Flooding
- Thermal management
- Integration of packaging for high fuel and oxidant packing density

Status

- 1st 80 cell stack completed
- Controller software developed
- 2nd stack assembly in progress
- Power plant test in September

A. F. Sammer Corp., Ringwood, New Jersey

Purpose

Develop chemical-hydride hydrogen source for PEM fuel cells

Phase 1 Accomplishments

- Tested various hydrides
- Control of hydrogen generation rate (load responsive generation)
- Design accomodated volume expansion of solid reactants

Phase 2 Proposal Submitted

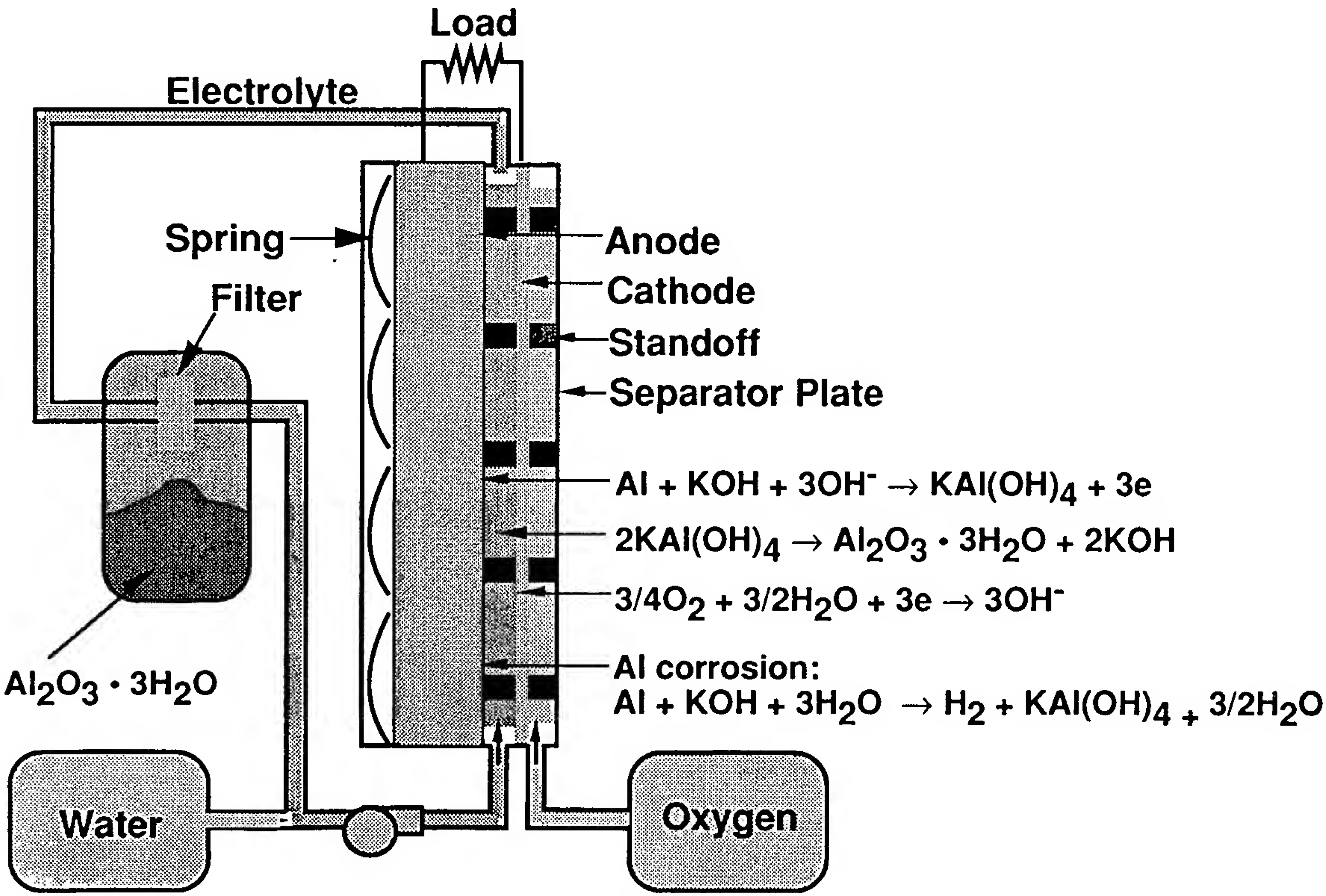
- Build system for use with PEM fuel cell in ARPA UUV

Semi-Cell Power Systems

Issue: Improved energy density

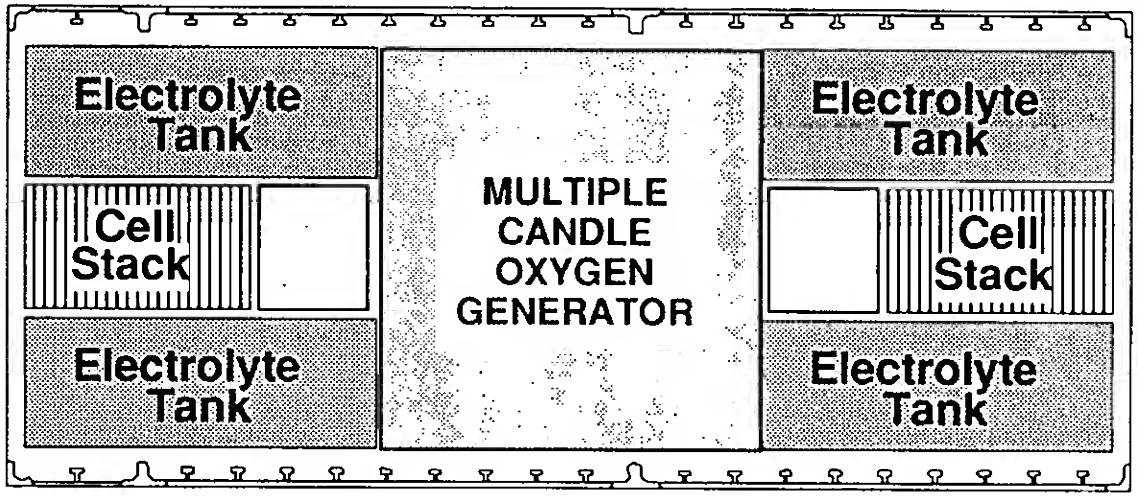
Candidate	Use and Issues	Energy
Aluminum hydrogen peroxide	Demonstrated in laboratory by NUSC for torpedo application.	900 kWh in UUV
Aluminum oxygen	*High energy density, anode corrosion, product removal.*	*1300+ kWh in UUV*
Aluminum silver peroxide	NUSC developing for torpedoes. Demonstrated in laboratory. High rate of corrosion. Hard to power down.	1600 kWh in UUV
Lithium oxygen	Similar to Al-Oxygen, but very difficult to control. Energy gain.	1830 kWh in UUV

Aluminum / Oxygen Semi-Cell



Semi-Cell Power System

Aluminum / Oxygen Semi-Cell



Loral / Eltech / NUWC

Technical Challenges

- Anodes
  - High current generation
  - Low parasitic corrosion
- Cathodes
  - Catalyst wetting without flooding
- Removal of aluminate from electolyte
- Thermal management

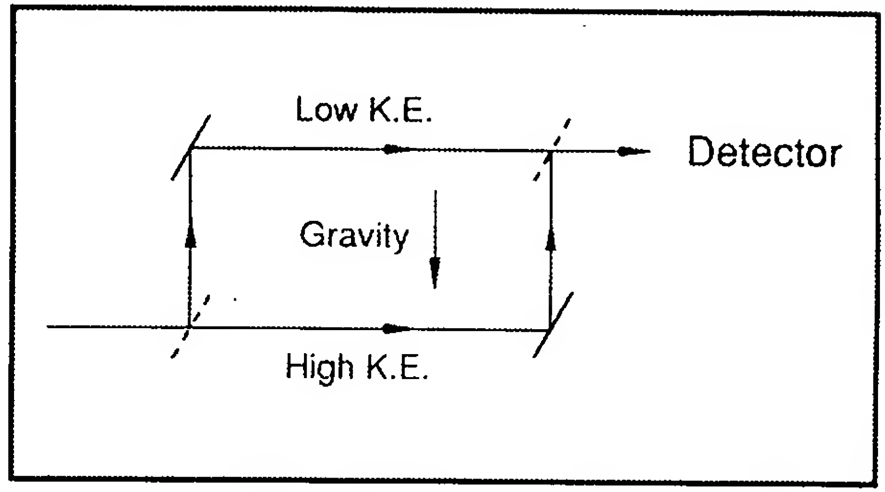
Status

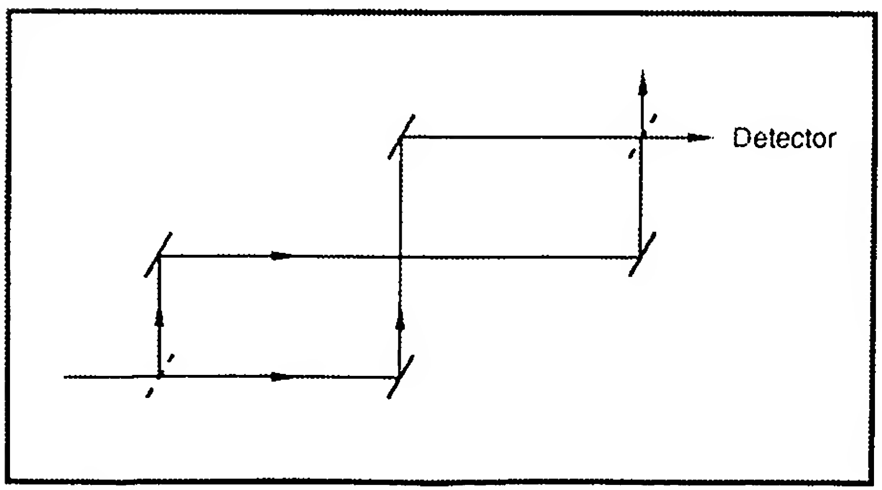
- Full scale single cell testing
- Examining non-uniform cathode reaction
- NUWC MCOG program initiated

Atomic Interferometer

- Utilize wave properties of atoms to detect inertial effects
- Analogous to ring laser gyros
- Extremely sensitive (10^4 improvement)
- Potential for gyroscopes, accelerometers, gravitometers, gravity gradiometers

Wavelength - 1 Angstrom

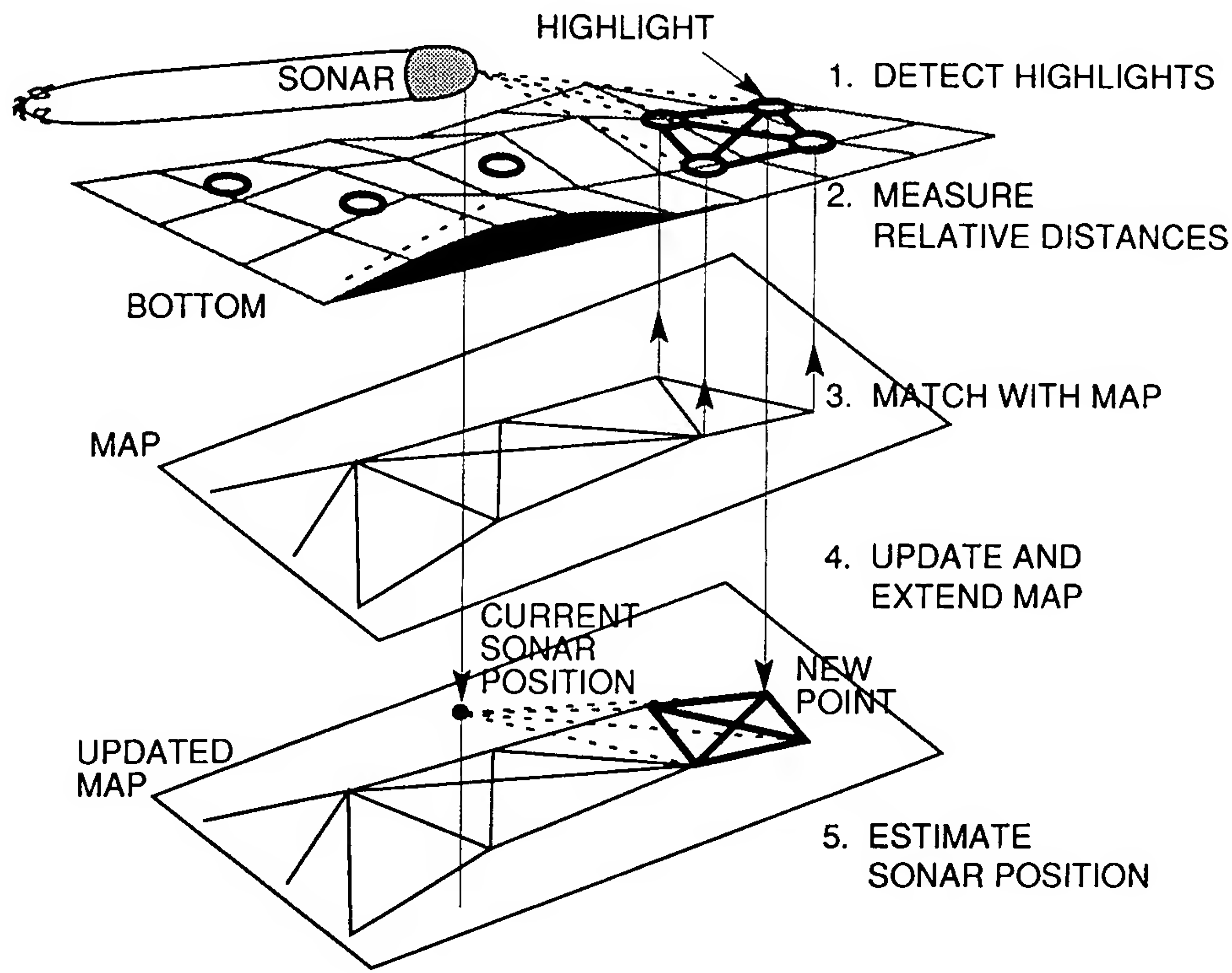




Gradiometer Implementation

- The phase shifts from rotation or acceleration have the opposite sign in the two loops and cancel out
- Signal is proportional to gravity gradient
- Easier to implement due to insensitivity to vibrations, etc.

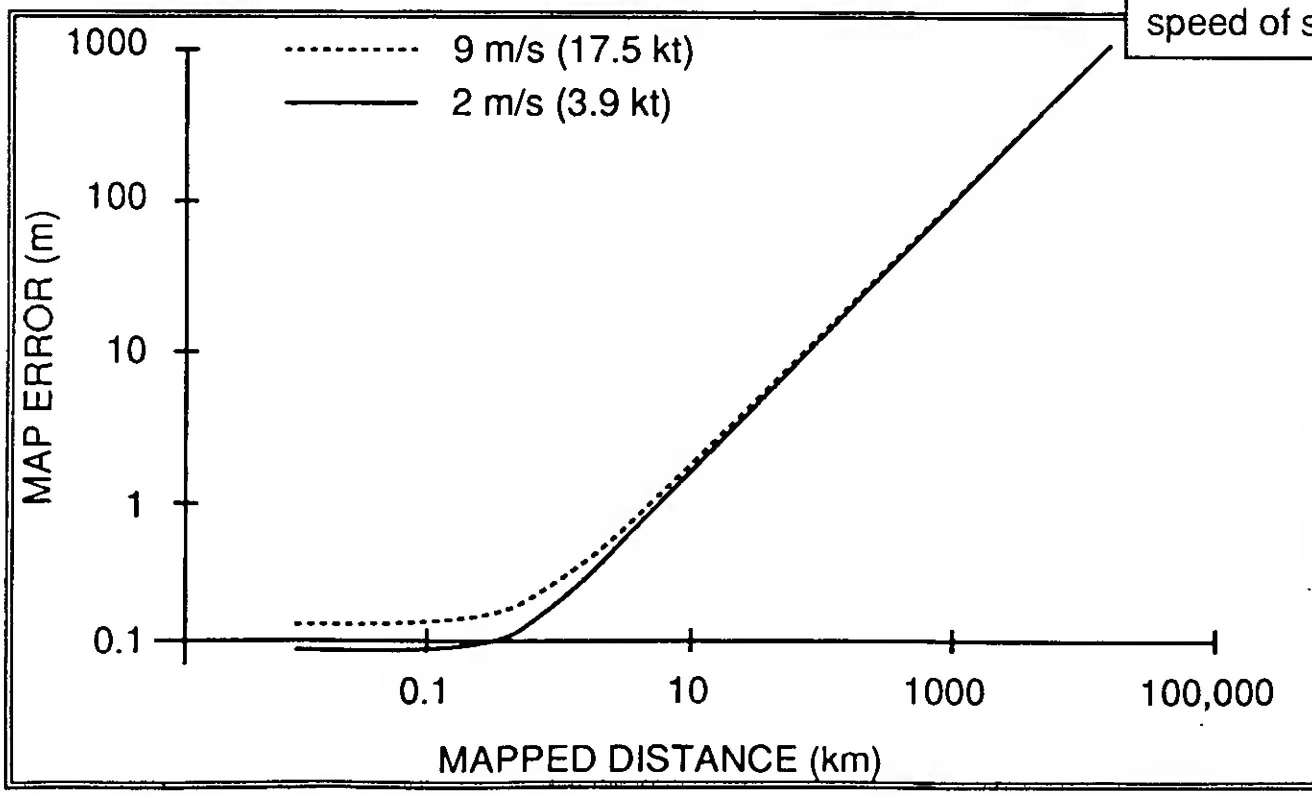
Sonar Aided Navigation



Sonar Aided Navigation Accuracy

Parameters

height above bottom	50 m,
range scale	2000 m
sector width	150°
area coverage	2.6×10^6 m^2
highlight density	1.5×10^{-5} m^{-2}
number of detections	10 @ 9 m/s, 45 @ 2 m/s
range uncertainty	0.5 m
elevation uncertainty	0.5°
speed of sound bias	0.15 m/s



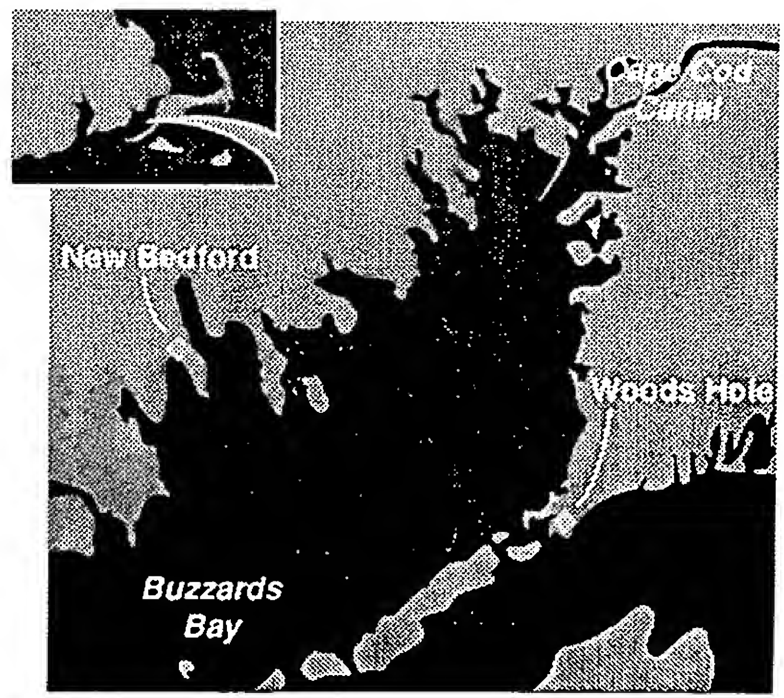
Acoustic Communications

Technical Concepts

- Coherent signal processing (4X bandwidth efficiency compared to incoherent)
  - Single receiver
  - Multiple receivers
- Diversity
  - Spatial (multiple receivers)
  - Temporal
  - Spectral
- Doppler tracking

Buzzards Bay test

- 20 Kbit/sec at 4 nm
- Water depth 20-40 feet
- 0-7 knots doppler correction
- Modulation format: QPSK, QAM
- Transmitter 12-20kHz,185 dB re uPa



Acoustic Local Area Network

Goal: Provide robust communications in very shallow water

Approach: Autonomous routing of messages between acoustic network nodes

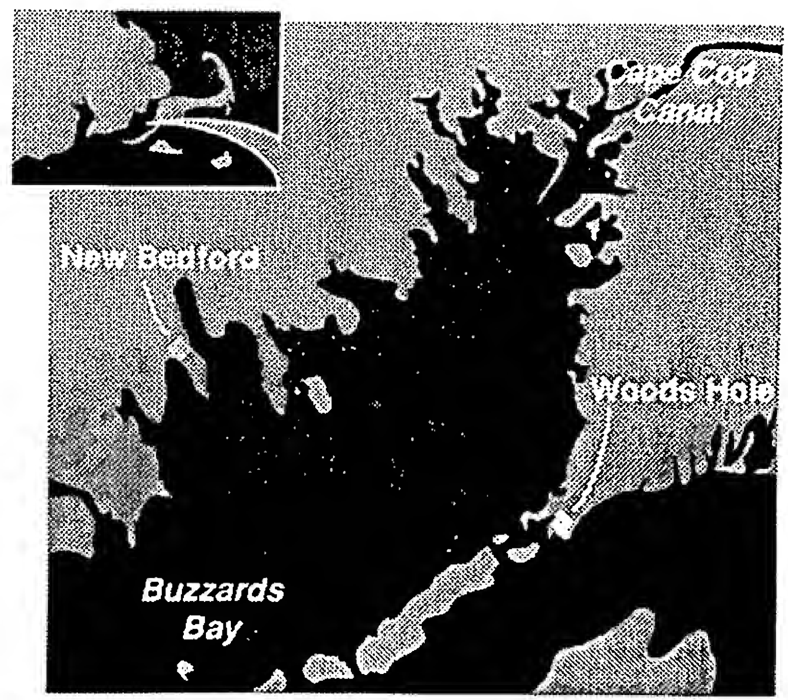
Issues: Message contention, error detection/correction, netowrk control

Data: Overall throughput - 50 kbps @ 5-10 km
Individual platform - 10-20 kbps

Power: >1000 bits/joule/km

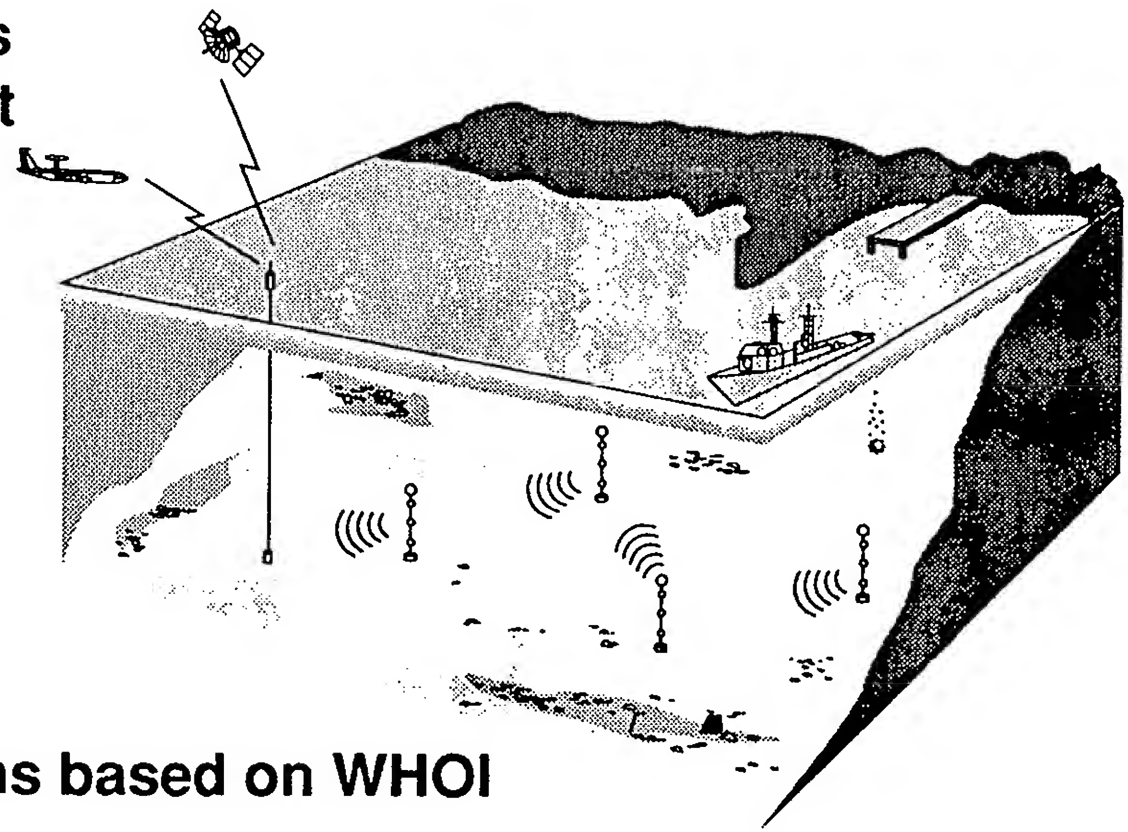
Interface: Digital RF to shore, satellite

Status: pilot telemetry experiments Feb 92
prototype system under construction
first network deployment in Fall 93



Autonomous Surveillance Network

- Develop a surveillance buoy system rapidly deployable by diverse platforms, including UUVs for detection of:
  - mine laying operations
  - submarine deployment
- Multiple sensor types
  - passive acoustic
  - active acoustic
  - magnetic
  - E-field
- Fuse multiple buoy data
- Inter-buoy communications based on WHOI technical developments



Autonomous Surveillance Network

MSTO

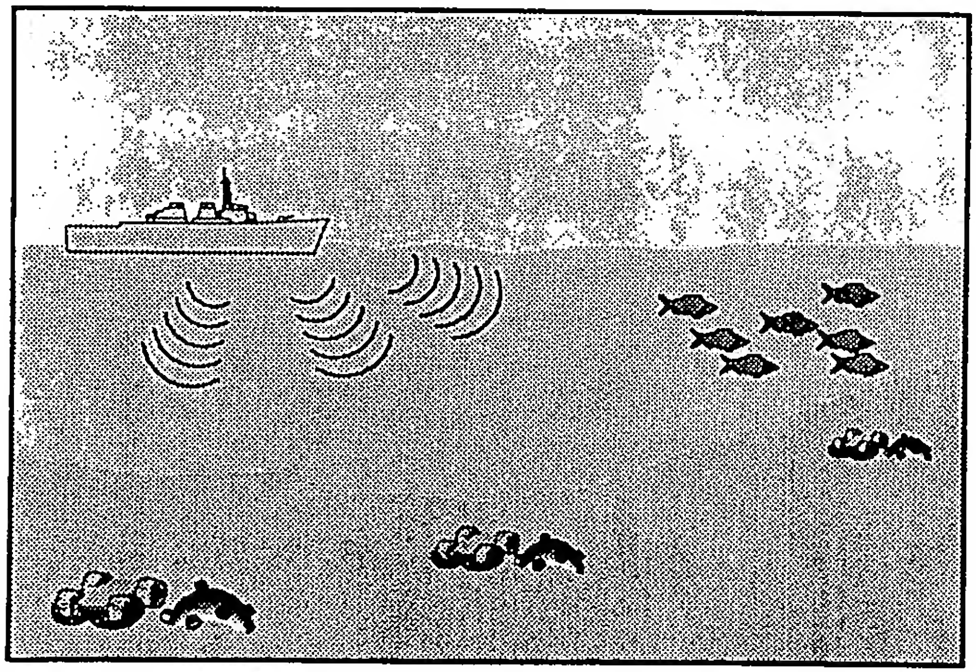
Technical Challenges

- High Pd, low Pfa
- In-situ processing
- Miniaturization
- Autonomous Control
  - Across nodes (e.g., ping management, tracking)
  - Selectable processing
- Sensor cost

Magnetic Communications

Objective

Develop underwater magnetic communication system for shallow water applications where acoustic communications are limited to short range



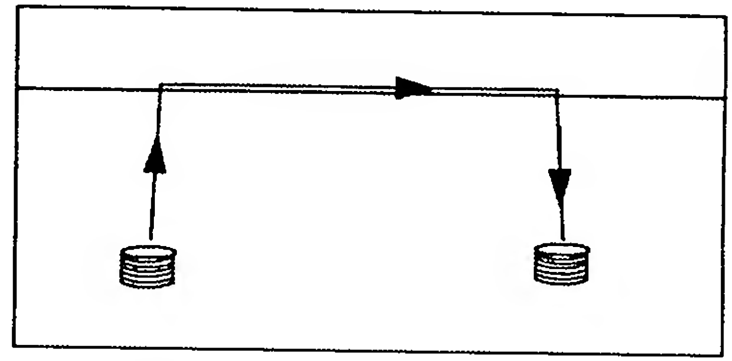
APPLICATIONS

- Simultaneous command detonation of charges placed near mines
- SPECWAR communications
- Surface / subsurface communications
- Inter array communications

CHARACTERISTICS

- Covertness (operation outside the conventional spectrum)
- Low susceptibility to jamming
- Operable in both air and water

Magnetic Communications



Phenomenon Exploited

- Lateral electromagnetic wave along the boundary between seawater and air
- Critical angle of 6.4 degrees

Technologies Exploited

- New material / processes for magnetic sensors
  - Amorphous magnetic alloys
  - Magneto--strictive material deposition technologies
- Signal processing electronics developments

Critical Issues

- Experimental validation of performance predictions (range, data rate)
- Size and power consumption of transmitter
- Size of receiver